

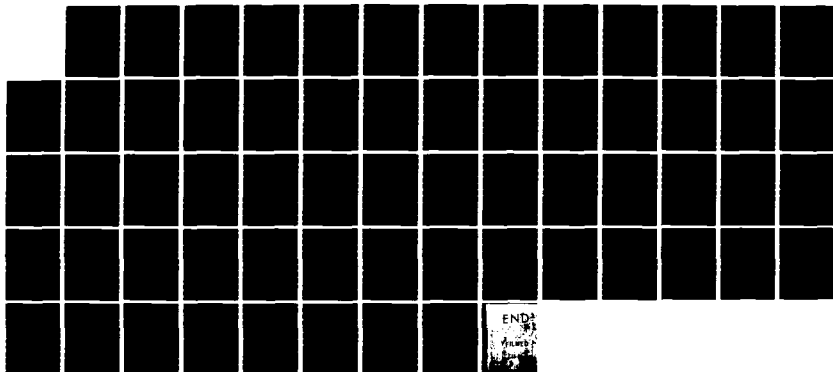
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DEMAND FORECASTING AND REVENUE REQUIREMENTS WITH
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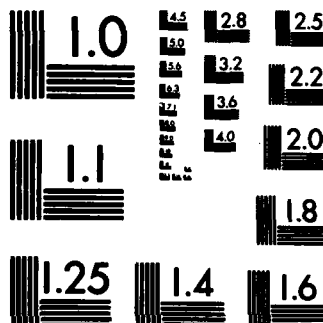
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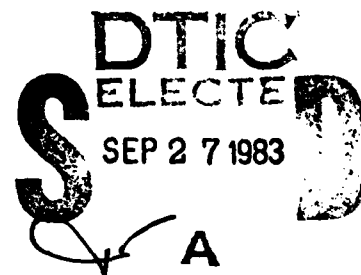
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DEMAND FORECASTING AND REVENUE REQUIREMENTS,
WITH IMPLICATIONS FOR CONSIDERATION IN BRITISH COLUMBIA

Jan Paul Acton

May 1983



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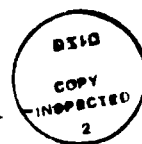
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PREFACE

Until recently Canadian electrical utilities have received little regulatory review on matters of setting their electrical rates when compared with their U.S. counterpart utilities. Provincial regulatory boards have generally reviewed matters such as capital construction programs and overall level of electrical rates, but have not undertaken a detailed review of costs, alternative rate structures, and interclass comparisons of rates and costs. This has started to change within the last few years, with major reviews undertaken in Ontario and British Columbia. Because these are often the first discussions on many of the topics, these early cases have assumed many characteristics of a "generic rate" case proceedings--where considerable discussion focuses on principles of ratemaking rather than the fine tuning of an existing rate structure and set of relationships among customer classes.

The British Columbia Hydro and Power Authority became subject to general regulatory jurisdiction for the first time in September 1980. Among other things, this meant that any changes in gas or electric rates must have the prior approval of the B.C. Utilities Commission. The first such application was filed in June 1981 and hearings took place between January and December, 1982. The Utilities Commission's decision was issued February 28, 1983.

→ This paper was filed as an exhibit on behalf of The Consumers' Association of Canada (B.C. Branch), The Federated Anti-Poverty Groups of B.C., The Sierra Club of Western Canada, and the B.C. Old Age Pensioners' Organization. It was subjected to cross-examination on →

→ October 29, 1982, during Phase I of the hearings. The Utilities Commission had designated Phase I for consideration of (i) demand, (ii) assets in service, (iii) revenue requirements excluding return, and (iv) financing and capital requirements. Phase II was scheduled to consider such matters as rate structures. The Utilities Commission undertook to issue a decision after each phase. Their 1982 hearings and the February 1983 decision applied to Phase I. Phase II has not begun, and may await the next general rate filing by B.C. Hydro.

→ This paper presents a general discussion of the elements of a rate structure and their relationship to the demand for electricity, a systematic review of some 50 empirical studies of the demand for electricity as a function of price and other factors by the three principal classes of customers, and a discussion of the notion of "revenue requirements." The paper should be of interest to utility regulators, rate specialists, and forecasters for its review of demand models and to academics concerned with the study of energy demand.

In preparing this paper I benefitted from useful discussion with R. J. Gathercole and Ms. L. Parsons, attorneys for the B.C. Public Interest Advocacy Centre, and the research assistance of Yilmaz Arguden.

PREPARED EVIDENCE OF JAN PAUL ACTON

Phase I Hearings, Revenue Requirement

3 Prepared on Behalf of The Consumers' Association of Canada (B.C.
4 Branch), The Federated Anti-Poverty Groups of B.C., The Sierra Club
5 of Western Canada, and the B.C. Old Age Pensioners' Organization.

6 Q1 Please state your name and address.

7 A1 My name is Jan Paul Acton. I reside at 364 21st Place,
8 Santa Monica, CA 90402. I am employed as a Senior
9 Economist at the Rand Corp., but I am appearing in these
10 proceedings as an individual and not as a representative
11 of the Rand Corp. My education and professional
12 qualifications are set forth in Appendix A.[1]

13 Q2 What is the purpose of your testimony?

14 A2 To discuss the relative importance of prices in load
15 forecasting, to present empirical evidence of magnitudes
16 of price response that are most applicable to the
17 deliberations in British Columbia, and to draw
18 implications for rate determination in B.C. Hydro.

19 Q3 Please outline your prepared testimony in this phase of
20 the hearing.

[1] Appendix A omitted from Rand reprint of this testimony.

21 A3 First, I will review briefly the important elements of
22 rate structures used in this discussion.

23 Second, I will review empirical studies of the demand for
24 electricity with particular emphasis on the role of
25 prices. My review will include an emphasis on Canadian
26 studies and non-Canadian studies that are especially
27 relevant to a rate case in Canada.

28 Third, I will discuss some implications of these studies
29 for revenue "requirements" and load forecasting in the
30 B.C. Hydro system.

31 Q4 Are there important aspects of the discussion that are not
32 covered in your present testimony?

33 A4 Yes. It is my understanding that this phase of the
34 hearings is to focus, among other things, on load
35 forecasting and on revenue requirements and that
36 discussions of rate structures are to take place primarily
37 in Phase II of the hearings. It is difficult to discuss
38 the role of prices in load forecasting and determination
39 of revenue requirement without some attention to the
40 elements of the rates. Empirical evidence and common
41 sense suggest that price sensitivities differ by different
42 elements of the rates structure as well as overall rate
43 level. For example, customers may be price sensitive in
44 general, but may display virtually no response to a change
45 in the monthly customer charge.

46 In my testimony, I will try to follow the Commission's
47 guidelines by discussing in Phase I price elasticities
48 with respect to overall expensiveness of electricity and
49 concentrate on non-time of day rate structures. I will
50 discuss in Phase II elasticities with respect to specific
51 rate structures. I will also reserve my recommendations
52 for modification of present rate structures--or
53 introduction of new rate structures--for Phase II of the
54 hearings.

55 I. Definition of the Major Elements of Rate Structures Used
56 in this Discussion

57 Q5 What are the major elements of a rate structure?

58 A5 There are three major components of an electrical rate
59 structure that are relevant to our discussion: (a) the
60 customer charge, (b) the kw demand charge, and (c) the
61 energy charge.

62 a. CUSTOMER CHARGE is a fixed charge (usually monthly or bi-
63 monthly) that the customer must pay, regardless of the
64 amount of consumption in the time period, in order to
65 receive electrical service. Sometimes this amount is
66 recovered from the customer through a minimum bill per
67 time period.

68 b. kw DEMAND CHARGE applies to the maximum rate at which
69 electricity is consumed in a very brief time period--
70 measured in kilowatts (kw). On some meters, the charge is

71 applied to the maximum instantaneous amount; with other
72 meters, it is applied to the maximum average demand over a
73 period of 15 or 30 or 60 minutes.

74 c. ENERGY CHARGE applies to the total amount of energy
75 consumed--measured in kilowatt hours (kwh).

76 Q6 Are there other important definitions that underly the
77 analysis of non-time of day rates?

78 A6 Yes, the most important is the use of block rate
79 structures. These may be applied to either energy or kw
80 demand charges. In a block rate structure for energy
81 charges, the first so many kwh are priced at one level,
82 the next so many kwh are priced at a different level, and
83 so forth for as many blocks as the rate authority
84 authorizes. For example, in a declining block rate
85 structure the first 150 kwh per month might be priced at 5
86 cents/kwh; the next 250 kwh per month might be priced at 4
87 cents/kwh, and remaining kwh might all be priced at 3
88 cents/kwh in that month. An increasing block rate
89 structure would be defined analogously with prices rising
90 in steps as monthly consumption increases.

91 Block rate structures are found in some kw demand charges
92 as well. They may operate directly on the price charged
93 per kw of maximum demand per billing period or they may
94 work indirectly through the energy charge. For example, a
95 block extender rate has a variable price that is added to
96 the energy charge and is expressed in cents per kwh. In

97 one specific example, the charge added to the energy
98 charge might be 1 cent per kwh for the first 150 kwh per
99 kw of maximum demand per month; 0.8 cents per kwh for the
100 next 450 kwh per kw of maximum demand per month; and 0.6
101 cents per kwh for the remaining kwh per kw of maximum
102 demand per month.

103 The point of the definitions is that empirical studies
104 often distinguish some or all of these components in their
105 definition of "price" and then proceed to use one or more
106 component in their empirical analysis. Sometimes the
107 results differ importantly depending upon the components
108 used in defining "the price." Furthermore, if empirically
109 important differences are found, then forecasts of future
110 levels of demand should take account of what elements of
111 the rate structure are being varied.

112 II. Review and Discussion of the Demand for Electricity,
113 With Emphasis on Electricity Prices

114 A. Major Issues in Empirical Studies of Electricity Demand

115 Q7 What are the principal dimensions in which demand studies
116 vary that are important to these deliberations?
117 A7 In my opinion, if the primary use is for load forecasting
118 under different assumptions about price and related
119 factors, then the important differences involve

120 -- the selection of the price variables used in analysis,
121 -- the choice of unit of observation--whether aggregated
122 over groups of customers or whether the individual
123 customer serves as the unit of observation,
124 -- the choice of functional[2] form employed for
125 estimation,
126 -- whether the studies measure short or long run
127 response,
128 -- the degree to which the study adequately accounts for
129 other factors that may influence demand, and
130 -- the applicability of the findings estimated in one
131 geographic area to the conditions of another geographic
132 territory.

133 The first four factors are most important to assessing
134 price-related response. The latter two factors are most
135 important in predicting the level of use in a given
136 utility service territory, taking account of non-price
137 factors. When the primary application of a demand study
138 is to help assess the effects of price changes, then the
139 first four items are the most important--along with an
140 assessment of whether or not the treatment of the non-
141 price variables does or does not cause a bias in the price
142 related effects.

[2]The functional form refers to the mathematical representation of the estimating equations--for example, variables expressed in natural units, in their logarithms, in quadratic form, and so forth.

143 Q7 Please explain the difference between average price and
144 marginal price as used in demand studies.

145 A7 "MARGINAL PRICE" refers to the per unit price of a small
146 increment (or decrement) in consumption; it is the change
147 in the customer's bill that results from small changes in
148 level of use, divided by the amount of change in usage.

149 "AVERAGE PRICE" is the average of all prices the customer
150 faces. It is usually calculated as the total bill divided
151 by total consumption.

152 Q8 Could you give a simple example of the difference?

153 A8 Consider a customer who pays \$2.00 per month in customer
154 charge and 1 cent per kwh for energy. If he consumes 200
155 kwh per month, then his bill is \$4.00. In this case, the
156 \$2.00 customer charge is the inframarginal charge and the
157 1 cent/kwh is the marginal (or incremental) price. If the
158 consumer's use doubles to 400 kwh, then the bill does not
159 double; rather, it increases to \$6.00. Thus the marginal
160 price is the important determinant of price effects over
161 this range of adjustment.

162 Note that when the customer was consuming 200 kwh, his
163 average price was 2 cents/kwh; when he was consuming 400
164 kwh, the average price was 1.5 cents/kwh. Looking at
165 average price alone would suggest that his price was
166 declining, when in fact the per unit price associated with
167 additional consumption was constant.

168 In general, when a declining block rate structure is in
169 effect (eg, 5 cents/kwh for the first 150 kwh/month; 4
170 cents/kwh for the next 250 kwh/month; and so on), the
171 marginal price is the energy charge associated with the
172 block (or level of use) the customer currently faces. For
173 example, if the customer is consuming between 151 and 400
174 kwh, then the marginal price is 4 cents. The higher
175 energy charge associated with the first 150 kwh (as well
176 as any customer charge) is the inframarginal price in this
177 case.

178 Q9 But many customers do not seem to know the details of
179 their electrical rate structure. Is it not stretching
180 things to say customers respond to their marginal price
181 rather than average price?

182 A9 I do not think so. Customers certainly are affected by
183 their total bill; after all that is what they have to pay
184 at the end of each month. But when it comes to the
185 economic impact of changes in consumption, marginal prices
186 are more important. In the first place, many customers
187 are quite well informed about electricity charges. In the
188 instance of large commercial and industrial customers,
189 they may have a full-time person whose responsibility it
190 is to economize on energy use and that person will pay
191 close attention to the details of electricity rates.
192 Similarly, a number of residential customers have looked
193 closely at their rates and are informed about the effects

194 of marginal prices. Secondly, and more pragmatically,
195 through time, customers gain a feel for the effect on
196 their bills when their consumption varies, for example
197 from summer to winter or during holiday periods. When
198 consumption doubles, they realize that bills do not always
199 change by the same percentage as usage. Correspondingly,
200 when households conserve electricity by some amount (say
201 20 percent), their bills do not fall proportionately.

202 Q10 What is the importance of distinguishing marginal from
203 average price?

204 A10 It is important for statistical analysis and
205 interpretation and it is important for forecasting.
206 Consider the situation presented in the answer A8 above,
207 when 200 kwh led to a bill of \$4.00 and 400 kwh led to a
208 bill of \$6.00. If two customers were observed at these
209 consumption levels in a statistical demand study, then
210 using average price (rather than marginal price) would
211 lead one to conclude that a fall in average price from 2
212 cents/kwh to 1.5 cents/kwh would lead to a doubling of
213 electricity consumption. In fact, the price was identical
214 for the two customers and the inference of a price-
215 induced change would be spurious. Other factors are
216 causing the differences in consumption. If the analyst
217 were to use marginal price instead of average, the false
218 inference would not be drawn.

219 Q11 What is the problem with using average price in
220 statistical or econometric analysis?

221 All Primarily, it leads to bias in the estimated price
222 effects, which can lead to erroneous forecasts. This bias
223 is particularly important under a block rate structure or
224 a rate that has a significant customer charge in relation
225 to other charges (for at least a fraction of customers in
226 the statistical analysis).

227 Under a declining block rate schedule, the average price
228 per kwh approaches the marginal price as the quantity
229 consumed increases. For example, using the price
230 structure set out in answer A8 above, at 200 kwh, average
231 price is 2 cents/kwh and marginal is 1 cent/kwh; at 400
232 kwh, average price is 1.5 cent/kwh and marginal is 1 cent;
233 at 600 kwh, average price is 1.33 cent/kwh and marginal is
234 1 cent; and so forth. Thus the distortion between
235 marginal and average price is not uniform, and under many
236 important circumstances it will cause the apparent
237 (estimated) demand curve to depart from the true demand
238 curve.

239 A second bias is introduced when the average price is
240 measured by revenue per kilowatt hour sold. Even when
241 marginal prices are identical for customers drawn from a
242 cross-section of utilities, differences in either the
243 customer charges or inframarginal charge of the rate

244 schedules will cause the average price to vary, which can
245 lead to erroneous estimates of price effects.

246 Third, use of an average per-unit revenue measure
247 introduces a classic errors-in-variables problem by
248 including total consumption in the equation as both the
249 dependent variable and the divisor of one of the
250 independent variables. This will bias the estimated price
251 coefficient away from zero.

252 Finally, as illustrated in answer A10 above, if the
253 average price is used in the estimation equation, then
254 differences in consumption between consumers in the same
255 rate block that are due to unmeasured non-price factors,
256 such as weather or appliance stocks, will often be falsely
257 ascribed to a price effect. This, too, will bias the
258 estimated price coefficient away from zero.

259 Q12 Is this average price-marginal price distinction important
260 for the conditions in British Columbia?

261 A12 Yes, for two reasons. First, in some instances, forecasts
262 for British Columbia will be based in whole or part on
263 analysis from other service territories where the
264 distinction between average and marginal price is
265 important. Second, empirical studies conducted
266 exclusively with B.C. data must still distinguish average
267 from marginal price. In the B.C. Hydro rates for each of
268 the principal classes of service (bulk, general,

269 residential) there are declining block rate structures
270 (and sometimes increasing block features as well).
271 Therefore, both historic studies in British Columbia and
272 forecasting future demands should take that fact into
273 account.

274 Q13 What is the major consideration in studies using
275 aggregated as opposed to disaggregated data?

276 A13 The major problem with using aggregated data for empirical
277 analysis (e.g., all residential customers in a given utility
278 or province) is that it leads to averaging over customers
279 who often differ quite importantly in their individual
280 characteristics that account for electricity use. This
281 may mean averaging together households with important
282 differences in appliances (for example, those with
283 different type of space heating) or averaging across
284 industrial customers with important differences in their
285 equipment or production process. A particular example of
286 the problem caused by this type of averaging is that
287 aggregate data almost always force the analyst to use some
288 form of average--rather than marginal--price, with the
289 attendant problems of bias discussed immediately above.

290 Q14 How are you using the terms "short run" and "long run" in
291 this discussion?

292 A14 "SHORT RUN" is defined as the period of time over which
293 the customer makes no significant changes in capital
294 stocks. For residential customers, this means that

295 appliances, housing characteristics (number of rooms,
296 insulation, etc.), location, and the like remain fixed.
297 For industrial or commercial customers, it means that
298 equipment is not changed, building characteristics remain
299 the same, and that the firm does not relocate.
300 "LONG RUN" is defined as the period of time long enough to
301 permit customers to make major changes in capital
302 equipment, building characteristics, and location if they
303 choose to do so.

304 Pragmatically, the short run would apply to periods of
305 several months up through a few years for most customers.
306 The long run would encompass the period five or more years
307 after a change in price or other explanatory variable.

308 Q15 How is the term elasticity defined, and why is it used by
309 economists in discussions of demand?

310 A15 "ELASTICITY" is defined as the percentage change in
311 consumption divided by a given percentage change in the
312 value of an explanatory variable. The most commonly used
313 measures of elasticity are price elasticity of demand and
314 income elasticity of demand--although in principle,
315 elasticity could refer to anything (for example, the
316 temperature elasticity of demand, to indicate the
317 percentage change in use with a given percentage change in
318 temperature). In the specific case of electricity, the
319 price elasticity of demand for electric energy would be
320 the percentage change in (say) monthly electricity use

321 divided by the percentage change in price.

322 Economists often use elasticity to summarize the measure
323 of price responsiveness (or income responsiveness, etc.)
324 because it does not depend on the units in which
325 consumption and price are measured. Since both values are
326 expressed in percentages, then consumption can be measured
327 in kilowatt-hours or megawatt hours or joules of energy
328 and the same answer results. Similarly, price may be
329 expressed in dollars or cents or British pounds without
330 loss. This is particularly useful when a regulator or
331 analyst is considering the applicability of a demand study
332 from one area to another service territory; as long as the
333 consumer behaviour under consideration is believed to be
334 applicable to present circumstances, then it does not
335 matter if the original demand study were conducted using
336 different units of measure than the present application
337 calls for.

338 B. Review of Residential Studies of Demand

339 Q16 What studies did you review in preparing this testimony?

340 A16 I reviewed approximately 50 studies. They contain a
341 variety of sources of data, level of aggregation, types of
342 models employed, and so forth. The studies are listed in
343 the references at the end of my testimony. I also
344 reviewed the surveys prepared by Taylor, Anderson, Nemetz

345 et al, and Denny, Fuss, and Waverman. Details of my review
346 are contained in Appendix B. The major characteristics of
347 studies I reviewed are summarized on pages B1-B3.
348 Residential sector price and income elasticities are
349 reported on pages B4-B7. Long run appliance saturation
350 elasticities are reported on page B8. Commercial sector
351 price and income elasticities are reported on pages B9-
352 B10, and industrial sector price and output elasticities
353 are reported on pages B11-B13.

354 A wide range of findings are reported, although findings
355 are much more comparable when disaggregated studies are
356 used and when comparable definitions of price are used.
357 Based on my review of this literature, I would suggest the
358 following range of values that are likely to encompass the
359 true value of price elasticity applicable to the B.C.
360 Hydro system in the short-run and in the long-run. These
361 are necessarily judgmental statements on my part, but I
362 think many other analysts would come to comparable
363 conclusions after reviewing a similar set of studies. The
364 range of values is intended to be wide enough to include
365 the true value of price elasticity with a probability of
366 80 percent. That is, if one takes the range of values I
367 suggest, then the actual elasticities in any particular
368 instance would be encompassed by this "confidence band" 80
369 percent of the time.

TABLE 1
ACTON'S ESTIMATES OF RESIDENTIAL PRICE ELASTICITIES OF DEMAND
FOR ALL HOUSEHOLDS

SHORT RUN			LONG RUN		
low	medium	high	low	medium	high
-0.12	-0.20	-0.35	-0.60	-0.90	-1.20

370 Q17 Are there other studies that survey price elasticity of
371 demand from several empirical investigations?

372 A17 Lester Taylor reports the results of a survey published in
373 the Bell Journal of Economics, Spring 1975 in which he
374 reviews studies through the early 1970s. I am only aware
375 of one other study that presents a similar explicit review
376 and tabulation of probable elasticity values--having
377 reviewed recent studies. It is the paper by Kent Anderson
378 of NERA entitled "A REVIEW OF STUDIES OF THE DEMAND FOR
379 ELECTRICITY," September 20, 1981 prepared for B.C. Hydro
380 and entered as Exhibit 32 in the Site C hearing. I
381 reviewed Anderson's study before preparing my testimony
382 and have followed a number of his classification
383 conventions to facilitate comparisons.

384 The chief differences between Anderson's method of review
385 and my own are: (1) Anderson reviewed a number of older
386 studies whereas I concentrated on studies published since
387 1975; in some cases, I have included recent studies that
388 were not available at the time Anderson prepared his

389 review. (2) I have deliberately included a number of
390 Canadian studies not in Anderson's review because I think
391 they are especially important in these deliberations.
392 Somewhat over one-third of the studies in my review are
393 specifically Canadian studies.

394 Anderson's findings and my own are generally quite
395 consistent, although my estimates tend to be a bit less
396 elastic (closer to zero). He describes his lower and
397 upper values as a range such that the odds are roughly 4:1
398 that the true elasticity lies within the limits. This is
399 the same confidence band as the 80 percent range I am
400 using.

TABLE 2

ANDERSON'S ESTIMATES OF RESIDENTIAL PRICE ELASTICITY OF DEMAND

SHORT RUN		LONG RUN	
lower=-0.15	upper=-0.30	lower=-0.70	upper=-1.50

401 Q18 How does price elasticity vary with level of use among
402 residential customers?

403 A18 There are relatively few studies of this effect directly,
404 although the evidence suggests that price elasticity
405 increases with level of consumption. That is, the
406 proportional price response increases with level of use--
407 on top of the fact that the absolute response is greater
408 because the amount of consumption is greater. Among other

409 things, this increasing price elasticity of demand is
410 implied by studies which allow for different elasticities
411 that are due to such characteristics as appliance
412 holdings.

413 In one such study (Acton, Mitchell, Sohlberg), the
414 researchers found that differences in appliance holdings
415 affect both the overall level of use and the price
416 elasticity of demand. These elasticities should be viewed
417 as reflecting short-run behavior, since they are based on
418 a particular stock of appliances. They are calculated as
419 follows:

TABLE 3			
RESIDENTIAL PRICE ELASTICITY ESTIMATES BY LEVEL OF USE			
0-150kwh/mo.	151-400kwh/mo.	401-1000kwh/mo.	1001+ kwh/mo
-0.25	-0.35	-0.44	-0.54

420 The elasticities are calculated for assumed appliance
421 holdings that are, respectively, one-half standard
422 deviation below the mean appliance holding, at the mean,
423 one-half standard deviation above the mean, and one
424 standard deviation above the mean. These appliance
425 holdings apply approximately to the range of monthly
426 consumption indicated.

427 Q19 What is the effect of weather on electricity demand? In
428 particular, how does it effect price responsiveness?

429 A19 In general, weather plays a very important role in the
430 level of electricity use. More extreme temperatures--both
431 hot and cold--increase use considerably. There is some
432 disagreement whether the effect is linear in degree-days
433 (or degree-hours) of temperature variation, but the effect
434 is clear and statistically significant whenever analysts
435 have examined it.

436 There has been considerably less attention given to the
437 question of the effects of weather on price sensitivity,
438 but when it has been analyzed, researchers have found
439 that--if anything--price responsiveness increases with
440 more extremely hot weather. Price responsiveness does not
441 seem to change as the weather gets colder. This may be
442 that--for a given increase in price--households are more
443 likely to turn off air conditioners when they leave a
444 house than they are to turn down (or off) electric
445 heating. See, for example, Lillard and Acton's study of
446 seasonal price responsiveness under a variety of seasonal
447 and non-seasonal electricity rates.

448 Q20 What is the effect of income as reported in these studies?

449 A20 The effect of income is largely reflected through the
450 purchase of appliances. All other things the same, higher
451 income households own more electricity-using appliances
452 and they tend to live in larger houses. Consequently, the
453 effect of income is mainly to increase usage in the long
454 run. When short-run demand models are estimated, and when

455 the analyst includes appliance holdings as explicit
456 explanatory variables, then the short-run income
457 elasticity of demand for electricity is found to be very
458 small and/or not statistically significantly different
459 from zero.

460 Q21 How do studies that focus especially on demand in Canada
461 compare with the studies reviewed?

462 A21 Nine of the 34 residential studies that I reviewed use
463 Canadian data. These specific studies of residential
464 electricity demand in Canada produce findings consistent
465 with the finding just summarized.

466 Summary of Residential Demand Studies

467 Q21 Please summarize your findings for residential customers.

468 A21 The overwhelming conclusion of these studies is that the
469 level of price affects the quantity of electricity
470 demanded in both the short-run and in the long-run.
471 Although the magnitude of price elasticity may vary with
472 the data, price used, and other factors, the price effects
473 are statistically significantly different from zero by
474 conventional standards of statistical inference. These
475 empirical studies virtually rule out the possibility that
476 price and quantity are unrelated.

477 In general, price elasticity is found to increase (in

478 absolute value) with:
479 -- greater holding of appliances,
480 -- higher income levels,
481 -- hotter weather (but not in colder weather;
482 elasticities seem to remain stable as temperature falls
483 successively below 65 F), and
484 -- price elasticities are greater (in absolute value) in
485 the long-run than in the short-run.

486 C. Review of Commercial Studies of Demand

487 Q22 What are the principal findings of studies of commercial
488 demand for electricity?

489 A22 There are relatively fewer studies of commercial demand
490 than for residential demand. This may reflect greater
491 ease of obtaining data and modelling household response
492 than commercial response, and it may reflect a greater
493 concern for policy impacts in the residential sector.
494 Most studies of commercial demand group all commercial
495 customers into the same unit of analysis. Consequently,
496 both small and large retail stores, small and large
497 grocery stores, small and large office buildings,
498 customers in new and older structures (with widely
499 different insulation and weather control equipment), etc.,
500 are all grouped together--usually with no distinction or
501 allowance for these differences. Despite these
502 aggregations and lack of explanatory variables, the

503 price-related findings are comparable to those reported
504 for residential user. In my judgment, the following range
505 of values probably encompass the true price elasticity of
506 demand in the commercial sector, with probability 80
507 percent.

TABLE 4
ACTON'S ESTIMATED OF PRICE ELASTICITY OF DEMAND AMONG
COMMERCIAL CUSTOMERS

SHORT RUN			LONG RUN		
low	med	high	low	med	high
-0.10	-0.20	-0.35	-0.40	-0.80	-1.00

508 Q23 What did Anderson report in his survey of commercial
509 customers?
510 A23 Anderson performed a similar study that reviewed many of
511 the same studies and provides very similar estimates.

TABLE 5
ANDERSON'S ESTIMATES OF PRICE ELASTICITY OF COMMERCIAL CUSTOMERS

SHORT RUN		LONG RUN	
lower=-0.10	upper=-0.30	lower=-0.40	upper=-1.00

512 Q24 How do Canadian studies compare?
513 A24 Three of the eight commercial studies I reviewed use
514 Canadian data. These Canadian studies are consistent for
515 this class of customers. Little attention has been given
516 to differences in price elasticity under different weather

517 conditions in this class of customers.

518 Q25 Please summarize your findings for commercial customers.

519 A25 -- The quantity of electricity use is related

520 statistically to the price of electricity,

521 -- The magnitudes of response are similar to those

522 reported for residential users, although the studies

523 generally do not control well for non-price factors, and

524 -- Long-run price elasticities are greater (in absolute

525 value) than are short-run elasticities.

526 D. Review of Industrial Studies of Demand

527 Q26 What did your review of industrial studies reveal?

528 A26 There are a somewhat greater number of studies of

529 industrial demand than for commercial customers, but fewer

530 than for residential customers. Generally the analysts

531 used fairly aggregated data. They often provide separate

532 estimates for principal SIC classifications. Most

533 attention has been given to demand for electricity by

534 manufacturing customers; relatively little systematic

535 attention has been given to demand by non-manufacturing

536 customers or to agricultural, utility, or governmental

537 customer classes.

538 There is considerable variability in the measured price

539 elasticity of demand for electricity within the

540 manufacturing sector. The least price-responsive
 541 industrial groupings have considerably smaller (less
 542 elastic) price effects than either commercial or
 543 residential customers. The most price-responsive
 544 industrial groupings have price elasticities of demand for
 545 electricity that may be double that of residential or
 546 commercial users. Furthermore, there are important
 547 differences in the speed with which industrial customers
 548 appear to adjust to changes in electricity prices, leading
 549 to important differences in the relationship between
 550 short- and long-run price elasticities in this class of
 551 customers.

552 For example Anderson found the following ranges of values
 553 in his review of industrial demand studies.

TABLE 6
 ANDERSON'S ESTIMATES OF PRICE ELASTICITY OF DEMAND AMONG
 INDUSTRIAL CUSTOMERS

	SHORT RUN		LONG RUN	
	Lower	Upper	Lower	Upper
MANUFACTURING	-0.20	-0.40	-0.70	-1.30
Lumber &				
Wood Pdts	-0.40	-0.70	-0.70	-1.10
Pulp & Paper	-0.25	-0.35	-0.70	-1.60
Chlorine	-0.20	-0.45	-0.80	-1.60
Petroleum				
Refining	-0.20	-0.30	-0.20	-0.90
Cement	-0.10	-0.30	-0.50	-1.00
Primary Metals	-0.15	-0.25	-0.90	-2.00
Other Mfg	-0.20	-0.30	-0.70	-1.10
MINING	-0.10	-0.30	-0.40	-1.00

554 For purposes of my analysis, I feel that Anderson's lower
555 and upper values for all manufacturing are suitable guides
556 to the 80 percent confidence bound.

TABLE 7
ACTON'S ESTIMATES OF PRICE ELASTICITY OF DEMAND AMONG
INDUSTRIAL CUSTOMERS

SHORT RUN			LONG RUN		
low	med	high	low	med	high
-0.20	-0.30	-0.40	-0.70	-1.00	-1.30

557 Q27 Why do some industries seem to have relatively low
558 elasticities in the short-run in combination with
559 relatively large elasticities in the long run?

560 A27 I think the correct interpretation is that some industries
561 seem to have relatively little flexibility in their
562 production process in the short-run, but are capable of
563 significant adjustments in plant configuration in the long
564 run, when capital equipment--including perhaps
565 cogeneration capability--can be constructed with the price
566 of electricity taken into account. For example, pulp and
567 paper, chlorine, and primary metals have slightly below-
568 average price elasticities in the short-run, but above-
569 average elasticities in the long-run. This implies that
570 their demands are heavily determined in the short-run by
571 factors other than price and that there is little
572 possibility of substituting non-electricity inputs in the

573 short-run when electricity prices rise. In contrast, in
574 the long run, when plant and equipment can be varied,
575 there appears to be substantial possibility for
576 substituting non-electricity inputs or making other
577 adjustments that lead to a significant long-run price
578 elasticity of demand.

579 Q28 How do Canadian studies of industrial electricity use
580 compare with these general findings?

581 A28 Seven of the 13 studies I reviewed use Canadian data
582 exclusively or Canadian data in combinations with other
583 country's data. The results are quite consistent across
584 countries.

585 Waverman et al specifically examined this question and
586 found that other North American empirical studies were
587 highly consistent with their own findings using Canadian
588 manufacturing data estimated over comparable SIC code
589 disaggregations. Among other things, this suggests that
590 manufacturing processes are reasonably international in
591 character and somewhat less affected by variations in
592 "local habits" or differences in climate than may be the
593 case for residential users.

594 Industrial Response to Interruptible Rates

595 Q29 Are there other important aspects of customer demand that
596 are especially relevant to this phase of the hearings?

597 A29 Yes. In a few instances, industrial customers have faced
598 an interruptible electricity rate which has resulted in
599 significant reductions in electricity use on an occasional
600 basis.

601 In England and Wales, the Load Management Warning (LMW)
602 tariff provides a very strong price incentive for holding
603 down demand during a few hours of the year. I have
604 studied this program first hand and have talked with both
605 utility people and large industrial customers who face
606 these rates.

607 Under the load management tariff, firms agree in advance
608 to pay a charge for their average demand during the load
609 management warning periods and a charge for their maximum
610 demand in any LMW period during the year. In recent
611 years, the charge was about L10/kw of average demand and
612 L3/kw for maximum demand during LMW periods. In recent
613 years, only a few hours of load management have been
614 declared (and in no case have the number of hours exceeded
615 20 per year compared with the 50 allowed by the tariff).

616 Approximately 110 firms have elected to be under the terms
617 of the Load Management Warning tariff and they reduce
618 their collective demand significantly in declared load
619 management periods. On one occasion during the mid 1970s,
620 the Electricity Council analysts were able to observe the
621 effects of a load management warning while conducting a

622 routine load study, and they observed an average reduction
623 of 40 percent from normal winter weekday demand by the 110
624 firms on the LMW tariff. See Mitchell, Manning, and Acton
625 (1978, p. 113). This accounts to about 1300 megawatts of
626 reduction in all, which is about 11 percent of class load
627 and 3 of the entire system winter peak load in England and
628 Wales.

629 In the absence of a detailed load study conducted during
630 the load management period, we must approximate indirectly
631 the degree of reduction that occurs in response to a LMW
632 tariff.

633 Over all, the firms in this group total almost 570 MW of
634 demand during load management period as compared with a
635 (non-coincident) maximum demand of 2,733 MW throughout the
636 year. That is, demand during LMW periods averages 22
637 percent of non-coincident annual maximum demands for these
638 firms. For some firms, the average of 22 percent
639 represents an over-estimate of response because winter
640 demands are below other seasons of the year; for other
641 firms, the 22 percent average is the approximately correct
642 measure because the firms peak in the winter during
643 conditions that might result in a LMW being called.

644 We also performed regression analysis on load management
645 response, accounting for differences by major industrial
646 groups. The regressions indicate that the mean level of

647 demand during Load Management Warnings is about 40 percent
648 of the maximum annual demand for firms lacking self-
649 generation and about 20 percent for firms with self
650 generation. The steel, cement, and miscellaneous electric
651 heating industries each average about 20 percent of
652 maximum demand during Load Management Warning periods.
653 The overall response in this group is greater than this
654 summary indicates. The miscellaneous electric heating
655 load category excludes small electric arc furnaces--which
656 are uniformly at zero consumption during LMW periods.
657 Most other industries are not, on average, statistically
658 significantly different from the average of all these LMW
659 firms.

660 E. Applicability of Study Findings to British Columbia

661 Q30 How applicable are these findings to the situation of
662 British Columbia?

663 A30 Clearly the surveys of empirical studies suggest that it
664 is important to take into account the circumstances in a
665 particular area when estimating demand and making
666 forecasts. But the empirical studies also suggest that
667 there are important behavioral commonalities across
668 customers and across different utility systems. This is
669 especially true for studies of industrial demand for
670 electricity, where the underlying production processes are
671 often quite similar from one area to another. In addition,

672 there are important similarities in the behavior of
673 commercial and residential customers as well, particularly
674 when disaggregated data are used for estimation.

675 Q31 What is the relationship between the customer groupings
676 you have just reviewed--industrial, commercial, and
677 residential--and the types of service provided in the B.C.
678 Hydro area?

679 A31 The most important designation of service level used in
680 the B.C. Hydro system for both costing and ratemaking
681 purposes is defined by voltage level. For simplicity, I
682 will refer to the distinction as high voltage, medium
683 voltage, and low voltage to correspond to the three
684 principle voltage levels at which customers receive
685 service. High voltage refers to the level at which bulk
686 service customers receive service; virtually all of these
687 customers are industrial users and correspond well to the
688 industrial customers reviewed above. Medium voltage
689 service encompasses both commercial customers in the B.C.
690 Hydro system as well as many manufacturing customers--and
691 perhaps some master-metered apartment buildings. For
692 practical purposes, medium voltage service can be viewed
693 as a composite of commercial and industrial users. Low
694 voltage service is supplied to the smaller commercial
695 customers and almost all residential users. In the B.C.
696 Hydro system, the findings reported for residential
697 customers would be most applicable for the majority of low

698 voltage customers.

699 F. Conclusions of Empirical Analysis

700 Q32 Please summarize the principal findings that you consider
701 relevant to these deliberations.

702 A32 My principal findings for demand studies in general are:

703 1 First, price is important in estimating and forecasting
704 electricity demand. When price is properly accounted for,
705 virtually every empirical study finds that price effects
706 are statistically significant. The likelihood that this
707 price-quantity relationship is due to chance is virtually
708 zero.

709 2 It is important to distinguish short-run and long-run
710 response for each class of customer.

711 3 In absolute value, own-price elasticities are smaller in
712 the short run than in the long run.

713 4 Long-run price elasticities are generally more uncertain
714 than are short-run price elasticities.

715 5 In the short run, the level of demand depends primarily
716 on:

717 -- marginal price of electricity,
718 -- appliance holdings, and
719 -- weather.

720 6 In the short run, demand depends relatively little on
721 -- income (which has its primary effect through appliance
722 holdings) or

- 723 -- inframarginal charges in the rate structure.
- 724 7 In the long run, residential demand:
- 725 -- depends more importantly on the full rate structure,
- 726 -- may be influenced by customer charges as well as
- 727 marginal charges ,
- 728 -- depends importantly on appliances or equipment,
- 729 housing characteristics, and location.
- 730 -- Appliance choice (including rated capacity and
- 731 efficiency), in turn, probably depends on the full rate
- 732 structure and income.
- 733 8 For commercial and industrial customers, the customer
- 734 charge and inframarginal charges may affect major
- 735 locational decisions, production capacity, and decisions
- 736 regarding the use of cogeneration or combined heat and
- 737 power systems.
- 738 9 A lot more is known about elasticity of demand with
- 739 respect to energy (kwh) charges than elasticity with
- 740 respect to kw demand charges.
- 741 10 For empirical analysis, the use of average price versus
- 742 marginal price can be summarized as follows:
- 743 -- In the short run, marginal price is clearly superior
- 744 theoretically, econometrically, and on the basis of the
- 745 statistical findings.
- 746 -- Because major capital investment decisions and
- 747 locational decisions take account of the overall
- 748 expensiveness of using electricity (and not just the

749 marginal price), it may be less important to distinguish
750 marginal and average price in the long-run. Either price
751 measure appears to work reasonably well and other factors
752 are probably relatively more important in determining
753 demand.

754 11 Seasonal differences in price responsiveness have not been
755 studied as thoroughly as some other aspects of demand.
756 Seasonal differences in demand appear to depend chiefly on
757 temperature and appliance holdings--which in turn may
758 affect both level of demand and price elasticity of
759 demand. When seasonal price elasticities have been
760 analyzed explicitly, price responsiveness is found to
761 increase with
762 -- greater holdings of weather sensitive appliances and
763 -- more extreme weather when hot (but not when colder),

764 III. Implications of Demand Studies and Price Responsiveness
765 for Revenue Requirements in B.C. Hydro

766 Q33 What are the primary factors that influence revenue
767 "requirement" in B.C. Hydro's system?

768 A33 Although these are often referred to as revenue
769 "requirements," we should be clear at the outset that
770 these are expenditures, which vary with the amount and
771 condition of supply, and whose magnitude depends on
772 managerial efficiency, historically determined plant and
773 equipment, administrative review by bodies such as this

774 Commission, and the level and composition of energy sales.
775 There are a number of components of expenditure that can
776 be usefully grouped into six categories:

777 1. Servicing Historic Financial Obligations. These are
778 largely determined by historic decisions such as the
779 issuing of long term indebtedness. Their magnitude is
780 little affected by changes in consumption in the short-
781 run. The amount of future financing obligations will be
782 largely determined by the conditions of the financial
783 markets, the amount of construction activity that is
784 planned or undertaken, and the decisions regarding target
785 levels of interest coverage or debt/equity ratios (see
786 also points 4 and 5 below).

787 2. General administration and operation expense. The
788 amount of this expenditure is a managerial decision, much
789 of which is determined by historic staffing decisions and
790 the number of customers to be served. This expenditure is
791 certainly subject to managerial review and control for
792 efficiency purposes, but it is relatively little affected
793 by short-run changes in the level of energy use.

794 3. Running costs. These costs are most influenced by
795 changes in the level of energy use in the system. They
796 are often referred to as variable operating and
797 maintenance costs and they include maintenance and repair,
798 water rental rates, fuel costs, and the costs of purchased
799 energy.

- 800 4. Planning and construction of new facilities. In a
801 system such as B.C. Hydro, these can be a major cause of
802 expenditure. Based on projections of future levels of
803 demands, the utility plans and constructs generation,
804 transmission, and distribution facilities. These
805 facilities are capital intensive, long lived, and may
806 require long lead times for planning and construction.
807 Some combination of current revenue, retained earnings,
808 and new financing usually covers these expenses.
- 809 5. The level of interest coverage or debt/equity ratio
810 that the utility attempts to maintain. This target can
811 exert considerable leverage on the amount of outstanding
812 debt and the interest rates paid.
- 813 6. Offsetting these costs are export sales which serve to
814 reduce the net expenditure, or "revenue requirement," of
815 the utility system.

816 This is not intended to be a comprehensive discussion of
817 the matter. Rather it is intended to suggest which
818 categories of costs and expenditures are relatively pre-
819 determined over a given time period and which are subject
820 to variation. A rate structure is designed and rate
821 levels are set to reflect these costs and to meet the
822 financial obligations of the utility.

823 The important point is that unless customers are perfectly
824 price insensitive (price elasticity is zero), the level

825 and structure of rates will affect the quantity of energy
826 consumed in both the short run and the long run.
827 Therefore, rates will affect the (a) operating costs, (b)
828 the desirable amount and type of generating equipment, (c)
829 the long-run construction costs, (d) the financing costs,
830 and (e) the revenue of the utility.

831 As things currently stand, B.C. Hydro apparently does not
832 systematically incorporate the quantitative feedback
833 effect of rates on quantity demanded. This is a problem
834 for at least three reasons. First, depending on the rate
835 structure selected, this will result in either over-
836 collection or revenue shortfalls. Second, by failing to
837 account for price effects, the utility is likely to commit
838 to an inappropriate amount and composition of new capital
839 facilities (generation, transmission, and distribution
840 equipment). Third, since price elasticities may vary
841 importantly by customer group, ignoring price feedbacks on
842 consumption may have a differential effect on different
843 customer groups.

844 IV. Implications of Price Elasticities for for Future Load
845 Growth and Revenue Requirement (or Rate Level)

846 Q34 What do these price elasticities imply for future load
847 growth and revenue requirement in the B.C. Hydro system?

848 A34 In general, they mean that if electricity rates are
849 expected to rise in real terms (i.e., adjusted for
850 inflation) for one or more customer groups, then demand
851 will be less than it would have been otherwise. This may
852 mean that load growth still occurs--but at a slower rate--
853 -or it may mean an actual reduction in future usage.
854 Conversely, if prices are expected to fall in real terms,
855 then demand will be more than it would otherwise have
856 been.

857 Q35 What rate level effects do you project for the B.C. Hydro
858 system?

859 A35 It is impossible to project a specific impact in B.C.
860 Hydro until the level of price increase and rate structure
861 is known. There is a feedback between rates and load
862 growth--leading to revised rates and thence to revised
863 load forecasts. Furthermore, if capital plans are
864 adjusted (which they should be), then rates and revenue
865 targets should be adjusted again, setting up the sequence
866 of feedbacks. This problem can and should be solved by
867 the utility in making load forecasts and expansion plans.

868 In the absence of specific projected rate increases that
869 have already taken account of these price-quantity
870 feedbacks, I will take three levels of assumed real price
871 increase and summarize the estimates on load changes for
872 the short-run and the long-run for each of the three major
873 customer classes. These estimates are based on the tables

874 of elasticities provided above. For illustrative
875 purposes, I have selected real price increases of 5%, 10%,
876 and 15%.

877 The short-run estimates apply to the period immediately
878 after a price increase occurs. They reflect customer
879 behavior before they have a chance to make significant
880 changes in appliances, equipment, or location. The low
881 and high values are intended to span the range of true
882 response with probability 0.80.

TABLE 8
ESTIMATED SHORT-RUN LOAD CHANGES WITH THREE ASSUMED VALUES OF
REAL PRICE INCREASES

REAL PRICE CHANGE	CHANGE IN CONSUMPTION (%)					
	RESIDENTIAL		COMMERCIAL		INDUSTRIAL	
	low	high	low	high	low	high
5%	-0.6	-1.8	-0.5	-1.8	-1.0	-2.0
10%	-1.2	-3.5	-1.0	-3.5	-2.0	-4.0
15%	-1.8	-5.3	-1.5	-5.3	-3.0	-6.0

883 The long run is defined as a period of time long enough
884 after a price change for significant capital (and possibly
885 locational) changes to take place if the customer desires
886 it. I have selected 5 years for specificity and have
887 assumed that at least 80% of the long-run price
888 adjustments given above have occurred.

TABLE 9
ESTIMATED LONG-RUN LOAD CHANGES WITH THREE ASSUMED VALUES OF
REAL PRICE INCREASES (5 YEARS)

REAL PRICE CHANGE	CHANGE IN CONSUMPTION (%)					
	RESIDENTIAL		COMMERCIAL		INDUSTRIAL	
	low	high	low	high	low	high
5%	-2.4	-4.8	-1.6	-4.0	-2.8	-5.2
10%	-4.8	-9.6	-3.2	-8.0	-5.6	-10.4
15%	-7.2	-14.4	-4.8	-12.0	-8.4	-15.5

889 V. Conclusion

- 890 1 An increase in price will serve to dampen load growth.
- 891 All load forecasts should take account of price
- 892 responsiveness as well as other factors. Failure to take
- 893 account of price responsiveness in a period of rising
- 894 prices will result in overestimating future demand for
- 895 electricity and will generally lead to overinvestment in
- 896 net generating equipment.
- 897 2 Increasing the interest coverage ratio (or reducing the
- 898 debt/equity ratio) in B.C. Hydro will cause prices to rise
- 899 over what they would otherwise have been. The amount by
- 900 which rates are projected to rise due to the increased
- 901 interest coverage target of 1.3 to 1 is enough to reduce
- 902 load growth forecasts substantially over the next several
- 903 years.

904 3 Any additional increase in rates (for example, to expand
905 capacity) will have a dampening effect on load growth.
906 This dampening in demand should be taken into account in
907 producing a revised load forecast and associated plant
908 construction program.

APPENDIX

Tables and References

SELECTED CHARACTERISTICS OF THE MODELS SURVEYED

Study	Consumer Sector Evaluated	Time Period	Structure		Fuel Prices Used
			Equation Type	Equation Form	
	(1)	(2)	(3)	(4)	(5)
Routhakker-Verleger- Sheehan (1974)	R	1960-1969	Electricity	log-linear	none
Baughman-Joskow (1975)	R	1969	Total Energy Energy split Appliance	exponential logit logit	natural gas, number 2 fuel oil
Halvorsen (1975)	R	1961-1969	Electricity	log-linear, exponential (price variable logged)	all types of residential gas
Wilder-Willenborg (1975)	R	1973	Electricity	mixed log-linear, exponential (price variable logged)	none
Hyndman-Mathewson (1975)	R	1958-1971	Energy split Electricity	linear	oil, natural gas
Battalio-Kagel-Winkler- Winnett (1976)	R	1975	NA	NA	NA
Cohn-Hirst-Jackson (1977)	R	1951-1974	Electricity	log-linear	natural gas, fuel oil
Fuss-Hyndman-Waverman (1977)	R	1958-1971	Electricity	mixed log-linear, exponential	none
	C	1960-1971	Electricity	linear	Price variable expressed as a ratio of electricity to a substitute fuel: natural gas, coal or oil
	I	1961-1971	Total energy Energy split	translog	coal, liquified petroleum gas, fuel oil, natural gas, motor gasoline
McFadden-Paig-Kirshner (1977)	R	1975	Electricity Appliance	log-linear logit	none natural gas
Taylor-Blattenberger- Verleger (1977)	R	1956-1972	Electricity	log-linear	natural gas
	R	1961-1972	Appliance	log-linear for all appliances except linear for refrigerators	natural gas

SELECTED CHARACTERISTICS OF THE MODELS SURVEYED

Study	Consumer Sector Evaluated	Time Period	Structure		Fuel Prices Used
			Equation Type	Equation Form	
	(1)	(2)	(3)	(4)	(5)
Lynn (1978)	R	1959-1968	Electricity	linear, log-linear, exponential and mixed log-linear, exponential	natural gas
	C,I	1961-1968			
Chern-Just-Holcomb-Nguyen (1978)	R,C,I	1955-1974	Electricity	mixed log-linear, exponential (price variable logged)	natural gas: R,C,I; number 2 fuel oil: R,C; number 6 fuel oil: I; coal: I
Yang (1978)	R	1962-1975	Electricity	log-log	natural gas
Parthasarathy-Davis (1978)	R	1964-1974	Electricity	log-log	none
Denny-Pass-Haverman (1979)	I	1962-1975	Energy split Electricity	mixed log-linear	4 different types of oil, coal, coke, natural gas
Houthakker (1979)	R	1964-1976	Electricity	log-log	natural gas
Walker (1979)	R	1972-1975	Electricity	log-log	none
Pindyck (1979)	E	1960-1974	Total Energy Energy split	translog	solid fuel, liquid fuel, gas
	I	1963-1973	Total Energy Energy split	translog	solid fuel, liquid fuel, gas
Spenn-Beauvais (1979)	All	1960-1973	Electricity	mixed log-linear	number 6 fuel oil
Smith (1980)	R	1957-1972	Electricity	log-linear	natural gas
Chang-Chern (1980)	I	1959-1976	Electricity	double-logarithmic	oil, coal, natural gas
Sahli-Erdem (1980)	R,C,I	1963-1974	Energy split	double-logarithmic	oil, natural gas
Berndt-May-Watkins (1980)	R,C,I	1961-1976	Energy split Electricity	linear, log-linear mixed log-linear	combined "other" energy
Memetz-Ramkey-Zethoff (1980) (Reviews other studies)	R	1958-1971	Electricity	double-logarithmic, exponential, non-linear	none, heating oil natural gas
Chern-Dick-Gallagher-Holcomb-Just-Nguyen (1980) (Obtained from Chern et al., 1982)	R,C,I	1955-1976	Electricity	dynamically specified logarithmic Koyck	number 2 fuel oil, natural gas for R & C number 6 fuel oil, coal, and natural gas for I
Acton-Mitchell-Schilberg (1980)	R	1972-1974	Electricity	linear	natural gas

SELECTED CHARACTERISTICS OF THE MODELS SURVEYED

Study	Consumer Sector Evaluated	Period	Structure		Fuel Prices Used
			Equation Type	Equation Form	
(1)	(2)	(3)	(4)	(5)	
Hartman-Werth (1981)	R	1960-1975	Electricity	linear	none
Wills (1981)	R	1975	Electricity	linear	natural gas
Both (1981)	R	1974-1977	Electricity	linear, log-log	natural gas
Common (1981)	R	1968-1978	Electricity	log-log	none
Besen-Kirby-Megri-Wetzel (1981)	R	1973, 1975, 1976, 1978-79	Electricity	linear	none
Cocke-Smith-Johnston-Howard (?)	R	1975-1979	Electricity	log-log	none
Betancourt (1981)	All	1972-1975	Electricity	mixed log-linear	none
Chung-Aigner (?)	C, I	1975-1979	Electricity	translog	none
Colombia-Pacific Resources Group, Ltd. (1981)	All	NA	Energy split	NA	NA
Dent-Kim-Chen-Felipe-Flynn-Ioannov (1982)	I	1975-1980	Electricity	spline	fuel oil, natural gas
Archibald-Finifter-Moody (1982)	R	1975	Electricity	linear	none
McRae-Webster (1982)	I	1962-1976	Energy split	translog	natural gas, fuel oil, coal, motor gasoline, LPG
Chern-Just-Chang (1982)	R, C, I	1955-1976	Electricity	mixed log-linear	none
Hellweil-Margolis (1982)	All	1961-1980	Energy split	mixed log-linear	oil, gas
Lillard-Acton (1982)	R	1975-1977	Electricity	mixed log-linear	none

Note: NA indicates not available or not applicable.
R: Residential; C: Commercial; I: Industrial;
All: Non-differentiated total demand.

RESIDENTIAL SECTOR PRICE AND INCOME ELASTICITIES

Date	Study	Data		Price Elasticity		Income Elasticity		Type of Price	Notes
		Type	Time Period	Short-Run	Long-Run	Short-Run	Long-Run		
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
May 1974	Routhakker-Verleger-Sheehan	CS-TS: USA, States	1960-1971	-0.03/-0.09	-0.45/-1.20	0.13/0.15	1.60/2.20	M	
Feb 1975	Halvorsen ¹	CS-TS: USA, States	1961-1969	---	-1.00/-1.21	---	0.47/0.54	M*	¹ Results for structural equations.
May 1975	Hyndman-Matthewson	CS-TS: 4 Canadian Provinces	1958-1971	---	-0.107	---	0.332	A	
Dec 1976	Battalio-Kagel-Winkler-Winnett	NA	1975	0.0/-0.15 ²	---	---	---	NA	² Price changes are experimentally induced.
Jan 1977	Taylor-Blattenberger-Verleger	CS-TS: USA, States	1956-1972 1956-1972	-0.07/-0.08 -0.16/-0.66	-0.81/-0.82 -0.46/-0.30	0.09/0.10 0.22/0.57	1.05/1.08 1.00/1.36	M	³ First row of values, flow adjustment models. Second row, capital-stock models. Based on Anderson; not independently reviewed.
Mar 1977	Cohn-Hirst-Jackson	CS-TS: USA, States	1951-1974 1960-1974 1965-1974 1969-1974	-0.14 -0.20 -0.16 -0.14	-1.16 -0.89 -0.78 -0.47	0.02 0.10 0.06 0.16	0.16 0.46 0.43 0.56	A	
Aug 1977	McFadden-Puig-Kirshner	CS: USA, Households	1975	---	-0.66/-0.73	---	0.39	M	⁴ Elasticity calculated for Ontario, 1971, not significant at .05 level.
1977	Fuss-Hyndman-Waverman	CS-TS: Canada, Provinces	1958-1971	-0.14 ⁴	---	(positive) ⁵	---	M	⁵ Statistically significant at better than 0.01.
July 1978	Yang	CS-TS: USA, States	1962-1975	-0.567	---	0.309	---	M	

RESIDENTIAL SECTOR PRICE AND INCOME ELASTICITIES

Date	Study	Data		Price Elasticity		Income Elasticity		Type of Price	Notes
		Type	Time Period	Short-Run	Long-Run	Short-Run	Long-Run		
Oct 1978	Chern-Just-Holcomb-Nguyen	CS-TS: USA, States by census region	1955-1974	-0.33 -0.22 -0.35 -0.27 -0.31 -0.47 -0.57 -0.19 -0.08	-1.50 -0.60 -1.22 -0.73 -1.12 -0.95 -1.07 -0.43 -0.37	0.07 0.34 0.06 -0.01 0.21 0.30 0.27 0.45 0.01	0.32 0.91 0.19 -0.02 0.77 0.61 0.51 1.03 0.04	A	⁶ First row of values, New England; second row, Mid Atlantic; third row, East North Central; fourth row, West North Central; fifth row, South Atlantic; sixth row, East South Central; seventh row, West South Central; eighth row, Mountain; ninth row, Pacific. Results are for third stage least squares (3SLS).
Dec 1978	Parthasarathy-Davis	CS-TS: USA, States	1964-1974	-0.04 ⁷ -0.15 -0.19	---	0.71	---	M	⁷ Elasticities are for 3 marginal block prices.
1978	Lyman ⁸	CS-TS: USA, Areas served by 67 utilities for 10 geographic regions	1959-1968	---	-1.02 -1.15 -0.13 -1.05 -0.82 -1.17 -1.13 -0.58 -1.36 -0.19	---	0.17 0.55 0.24 0.35 0.30 0.08 -2.07 -2.14 -0.54 0.11	A	⁸ Elasticities are for the following regions: West Coast, Northwest, North Midwest, Middle Atlantic, Southwest, North Texas, South Texas, South, Florida and Gulf. Calculated at sample means.
June 1979	Boutheiller	CS-TS: USA, States	1964-1976	-0.111	-1.4	0.139	1.8	M	
1979	Walker	TS: A Texas community residents	1972-1975	-0.14	---	0.74	---	M	
1979	Pindyck ⁹	CS: 9 OECD countries	1960-1974	---	-0.30/-0.39 -0.25/-0.30	---	¹⁰ 1.00 1.00	A	⁹ First row of values is for Canada; second for U.S. at 1965 and 1973 means.
1979	Spamm-Beauvais	TS: A Virginia utility	1960-1973	-0.31 ¹¹	-0.44 ¹¹	0.64 ¹¹	0.91 ¹¹	M	¹⁰ Constrained to unity by assumption. ¹¹ Peak demand elasticities.
1980	Acton-Mitchell-Sohlberg	CS-TS: Los Angeles County census tracts	1972-1974	-0.35	-0.70 ¹²	0.38	0.40 ¹²	M	¹² Excluding March-April 1974 billings in which DWP curtailment ordinance was in effect.

RESIDENTIAL SECTOR PRICE AND INCOME ELASTICITIES

Date	Study	Data		Price Elasticity		Income Elasticity		Type of Price	Notes		
		Type	Time Period	Short-Run	Long-Run	Short-Run	Long-Run				
Apr 1980	Smith ¹³	TS: 27 Investor-owned utilities	1957-1972	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
											¹³ The results are for 2SLS. The range indicates values across 27 utilities.
1980	Sahi-Erdmann	CS-TS: 7 Canadian regions	1963-1974	---	---	---	-0.988	---	---	A	
1980	Brendt-May-Watkins	TS: Alberta	1961-1976	-0.24	-0.6	0.37	0.95	A,M			
Apr 1980	Nematz-Hankey-Zethoff	CS-TS: Canadian Atlantic Provinces	1958-1971	---	-0.29 ¹⁴ -0.19 ¹⁵	---	---	A,M			¹⁴ From Fuss-Waverman (1975) per household. ¹⁵ From Fuss-Hyndman-Waverman (1977) per household.
1980	Chern-Dick-Gallagher-Molcomb-Just-Nguyen	CS-TS: USA, States	1955-1976	-0.210 ¹⁶ -0.218 -0.349 -0.254 -0.299 -0.355 -0.392 -0.139 -0.076	-1.154 -0.618 -1.091 -0.700 -1.079 -0.728 -0.907 -0.373 -0.402	---	---	NA			¹⁶ Rows are for New England, Middle Atlantic, East North Central, West North Central, South Atlantic, East South Central, West South Central, Mountain and Pacific States, respectively.
Mar 1981	Lillard-Acton	CS-TS: Individual households Los Angeles	1975-1977	-0.0576	0.217						¹⁷ The principal long-run effects of income may act through housing value, appliances and pool ownership. Based on seasonal and non-time-of-day plans in the Los Angeles rate experiment.
May 1981	Hartman-Werth	CS-TS: USA, States	1960-1975	-0.19	0.9	M					
July 1981	Common	CS-TS: U.S.	1968-1978	-0.214	-0.212 ¹⁸	0.476	0.441 ¹⁸	A			¹⁸ From a partial adjustment model which showed that .937 was the ratio of long-run to short-run elasticity.
1981	Roth	TS: A south-western utility, residents in U.S.	1974-1977	-0.11 ¹⁹		A,M					¹⁹ The elasticity is for marginal price. Average price elasticity is +0.39.

RESIDENTIAL SECTOR PRICE AND INCOME ELASTICITIES

Date	Study	Data		Price Elasticity		Income Elasticity		Type of Price	Notes
		Type	Time Period	Short-Run	Long-Run	Short-Run	Long-Run		
Aug 1981	Besen-Kirby-Nagel-Metzel	(1) CS: USA	(2) 1973, 1975, 1976, 1978- 1979 ²⁰	(3) -0.40	(4) -0.90	(5) 0.13	(6) 0.22	(7) M	(8) ²⁰ 4 different data sets are used. The results reported here are for the most recent years (i.e., 1978-79).
1981	Betancourt	CS-TS: 6 U.S. utilities in different census regions	1972-1975 ²¹	-0.17 ²²	---	---	---	A	²¹ He has also used 1972-1976 period but obtained unexpected signs on some elasticities. ²² This is a peak demand elasticity and reflects only conservation, <u>no</u> shifting.
Oct 1981	Wills	CS: Massachusetts districts	1975	-0.27				M	
Nov 1981	Colombia-Pacific Resources Group, Ltd.	Canada	NA	-0.47 ²³				NA	²³ Peak demand elasticity.
	Coke-Smith-Johnston-Howard	TS: California	1975-1979	-0.15	---	---	---	A	
Jan 1982	Helliwell-Margolis	CS-TS: 4 Canadian regions	1961-1980 ²⁴	---	-0.53	---	---	F	²⁴ For some equations 1955-1980 data was used.
June 1982	Chern-Just-Chang	CS-TS: USA, States	1955-1976	-0.48 ²⁵ -0.39	---	0.15	---	A,M	²⁵ These elasticities refer to average and marginal price elasticities, respectively.
1982	Archibald-Finifter-Moody	CS: USA, States	1975	-0.39	---	0.11	---	M	

Note: A indicates average price.
M indicates marginal price.
M* indicates a theoretical model in which both average and marginal price elasticities are identical (price data was A or F).
F indicates a price for a fixed amount of electricity, either average or marginal price.
NA indicates not available or not applicable.
TS indicates time-series data.
CS indicates cross-sectional data.
CS-TS indicates pooled CS and TS data.
Elasticities between short- and long-run columns are ambiguously defined in the reference cited.

LONG-RUN APPLIANCE SATURATION PRICE ELASTICITIES

Date	Study	Data		Long-Run Price Elasticities								Notes
		Type	Time Period	Heater	Cooking Fuel	Clothes Dryers	Space Heating	Food Freezing	Air Conditioning			
									Room	Central	Dishwashing	
Feb 1975	Beughman-Joskow	CS: USA, States	1969	-1.77	-0.78	-0.53	-2.08	NA	NA	NA	NA	
Jan 1977	Taylor-Blattenberger-Verleger	CS-TS: USA, States	1963-1972	-0.26	-0.45	0.11	-0.87	-0.32	-0.42	-0.56	NA	¹ Based on Anderson's review. Not independently verified.
Aug 1977	McFadden-Fuig-Kirchner	CS: Households	1975	-1.95	NA	NA	-2.95 ²	NA	-0.17 ³	NA	NA	² Value is for water and space heating. Elasticity is positive for space heating alone.
												³ Not specified whether room, multiple room or central.

Note: NA indicates not available.
 CS indicates cross-sectional data.
 CS-TS indicates pooled cross-sectional and time-series data.
 Elasticities are evaluated at sample mean

COMMERCIAL SECTOR PRICE AND OUTPUT ELASTICITIES

Date	Study	Type	Data Time Period	Price Elasticity		Output Elasticity		Notes
				Short-Run	Long-Run	Short-Run	Long-Run	
1977	Puss-Ryndam- Haverman	(1) CS-TS: Canada, Provinces	(2) 1960-1971	(3)	(4)	(5)	(6)	(7)
					-0.31	(positive) ¹		¹ Elasticity with respect to retail sales; statistically significant at better than 0.01 level.
1978	Lyman ²	CS-TS: USA, Areas served by utilities for 10 regions	1961-1968	-3.64 -0.92 -1.33 -2.60 -1.15 -0.27 -4.56 -1.15 -0.75 -0.65		---	1.00 ³	² Figures in Col. (4) pertain to regions. Elasticities are for the following areas: West Coast, Northwest Mid Northwest, Midwest, Middle Atlantic Southwest, North Texas, South Texas, South, Florida and Gulf.
Oct 1978	Chern-Just- Holcomb-Nguyen ⁴	CS-TS: USA, states by census regions	1955-1974	-0.47 -0.33 -0.43 -0.09 -0.39 -0.66 -0.25 -0.48 -0.40	-1.31 -0.51 -1.60 -1.02 -1.27 -1.29 -1.60 -0.90 -0.66	0.25 5 1.22 5 0.20 5 NA 5 0.33 5 0.33 5 0.03 5 NA 5 0.31 5 0.18 6 0.51 6 0.08 6 0.02 6 0.10 7 0.20 7 0.03 6 0.54 7 0.78 7	0.70 5 1.88 5 0.76 5 NA 5 1.09 5 0.65 5 0.20 5 NA 5 0.52 5 0.51 6 0.78 6 0.30 7 0.25 7 0.25 6 0.34 7 0.39 6 0.17 7 1.01 7 1.31 7	³ Number of customers. Constrained to unity by assumption. Elasticity with respect to income per house - hold not reported. ⁴ First row, New England; second row, Mid Atlantic; third row, East North Central; fourth row, West North Central; fifth row, South Atlantic; sixth row, East South Central; seventh row, West South Central; eighth row, Mountain; ninth row, Pacific. Results are for third stage least squares. ⁵ Real income per capita. ⁶ Population. ⁷ Number of customers. Note 6 and 7 not reviewed.

COMMERCIAL SECTOR PRICE AND OUTPUT ELASTICITIES

Date	Study	Type	Data Time Period	Price Elasticity		Output Elasticity		Notes
				Short-Run	Long-Run	Short-Run	Long-Run	
1980	Sahl-Erdmann	(1) CS-TS: 7 Canadian regions	1963-1974	---	-1.388	---	(6)	(7)
1980	Brendt-May-Watkins	TS: Alberta	1961-1976	-0.95/-0.84 ⁸	---	---	---	⁸ These elasticities refer to 1961 and 1976, respectively.
1980	Chern-Mck-Gallagher-Helcomb-Just-Nguyen	CS-TS: U.S. states	1955-1976	-0.294 ⁹ -0.208 -0.289 -0.172 -0.355 -0.589 -0.171 -0.438 -0.205	-1.508 -0.348 -1.410 -1.154 -1.176 -1.201 -1.425 -0.873 -0.366	---	---	⁹ Rows are for New England, Middle Atlantic, East North Central, West North Central, South Atlantic, East South Central, West South Central, Mountain and Pacific States, respectively.
June 1982	Chern-Just-Chang	CS-TS: U.S. states	1955-1976	-0.58 ¹⁰		0.94		¹⁰ Mean of average price elasticities for the states.
?	Chung-Aigner	TS: 64 large customers of PGE	1975-1979	-0.079 ¹¹				¹¹ Non-weighted average of peak price elasticities.

Note: NA indicates not available, or not applicable.
 TS indicates time-series data.
 CS indicates cross-sectional data.
 CS-TS: indicates pooled CS and TS data.

INDUSTRIAL SECTOR PRICE AND OUTPUT ELASTICITIES

Date	Study	Data Type	Time Period	Price Elasticity		Output Elasticity		Notes
				Short-Run	(3)	Short-Run	(5)	
1977	Fuss-Ryndman-Waverman	CS-TS: Canada, 5 Regions	1961-1971		(4)		(6)	(7)
					-0.74 ¹		---	¹ Mean value for Ontario 1961-1971
								² Not reported.
								Electricity cost share declines as output increases indicating a value below 1.00.
1978	Lyman ³	CS-TS: USA, Areas served by utilities for 10 regions	1961-1968				1.00 ⁴	³ Figures in Col. (4) pertain to regions including West Coast, Northwest, North Midwest, Midwest, Middle Atlantic, Southwest, North Texas, South Texas, South, Florida and Gulf.
				-0.86		---		⁴ Number of customers. Constrained to unity by assumption. Elasticity with respect to income per household not reported.
				-1.59				⁵ The first row of values is for New England; second row, Mid Atlantic; third row, East North Central; fourth row, West North Central; fifth row, South Atlantic; sixth row, East South Central; seventh row, West South Central; eighth row, Mountain; ninth row, Pacific. Results are for third stage least squares (3SLS).
				-2.31				⁶ First row gives elasticities for Canada; second for U.S.
				-0.44				
				-1.64				
				-1.07				
				-3.52				
				-1.67				
				-2.58				
				-0.27				
Oct 1978	Chern-Just-Holcomb-Nguyen ⁵	CS-TS: USA, Regions	1955-1974					
				-0.06		0.50	1.14	
				-0.02	-0.16	1.01	1.55	
				-0.32	-0.04	0.74	1.28	
				-0.26	-0.54	0.25	0.83	
				-0.15	-0.87	0.21	1.03	
				-0.28	-0.71	0.48	0.96	
				-0.10	-0.55	0.17	1.03	
				-0.19	-0.62	0.38	0.80	
				-0.03	-0.39	0.32	0.90	
					-0.09			
1979	Pindyck ⁶	CS-TS: 9 OECD Countries	1959-1974					
				---	-0.61	---		
					-0.63			

INDUSTRIAL SECTOR PRICE AND OUTPUT ELASTICITIES

Date	Study	Data		Price Elasticity		Output Elasticity		Notes
		Type	Time Period	Short-Run	Long-Run	Short-Run	Long-Run	
Aug 1979	Denny-Puse-Waverman	(1) CS-TS: 20 Canadian industries in 4 provinces	(2) 1962-1975	(3) -0.531 ⁷	(4) -0.618 ⁷	(5) ---	(6) ---	(7) ⁷ Non-weighted averages for 20 industries.
May 1980	Chang-Chern ⁸	TS: USA, 16 industries	1959-1976	-0.61	-1.14	0.40	0.76	⁸ Elasticities are unweighted aver- ages for 16 indus- tries.
May 1980	Brendt-May- Watkins	TS: Alberta	1961-1976	-1.15/-1.04 ⁹				⁹ These elasticities refer to 1961 and 1976, respectively.
1980	Sahi-Dermann	CS-TS: 7 Canadian regions	1963-1974	---	-0.799			
1980	Chern-Dick- Gallagher-Holcomb- Just-Nguyen	CS-TS: U.S. states	1955-1976	-0.038 ¹⁰ -0.081 -0.391 -0.172 -0.077 -0.298 -0.111 -0.201 -0.041	-0.114 -0.114 -0.594 -0.595 -0.433 -0.541 -0.481 -0.421 -0.104			¹⁰ Data are for New England, Middle At- lantic, East North Central, West North Central, South Atlan- tic, East South Cen- tral, West South Central, Mountain and Pacific States, respectively.
May 1982	Dent-Kim-Chen- Felipe-Flynn- Ioannou	TS: For 11 Ontario industries	1975-1980	-0.203/-0.183 ¹¹ -0.213/-0.219 -0.185/-0.193	---	2.187/2.171	---	¹¹ Winter/summer noon hour price elastic- ities in 1975, 1978, 1980, respectively, in each row.
1982	McRae-Webster	CS-TS: ¹² Canada	1962-1976	-0.39 ¹³ -0.26 0.00 -0.29 -0.32				¹² Results without pooling across regions were better. ¹³ Elasticities are for Atlantic, Quebec, Ontario, Prairies, and British Columbia, respectively.

INDUSTRIAL SECTOR PRICE AND OUTPUT ELASTICITIES

Date	Study	Data		Price Elasticity		Output Elasticity		Notes
		Type	Time Period	Short-Run	Long-Run	Short-Run	Long-Run	
June 1982	Chorn-Juett-Chang	(1) CS-TS: U.S. states	(2) 1955-1976	(3) -0.51 ¹⁴ -0.85	(4) -1.17 ¹⁴ -1.92	(5)	(6)	(7) 14 Average price elasticities for New York and Nevada, respectively. These span the range. 15 Non-weighted averages of peak price elasticities.
?	Chang-Miguer	TS: 64 large customers of FGE	1975-1979	-0.11 ¹⁵	---	---	---	

Note: TS indicates time-series data.
CS indicates cross-sectional data.
CS-TS indicates pooled CS-TS data.
Elasticities between short- and long-run columns are ambiguously defined in the reference cited.

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